

CLAIMS

1. A producing method of carbon nanofibers, wherein carbon nanofibers are caused to grow on surfaces of fine particles, the fine particles and fine particles with grown carbon nanofibers are recovered,
5 the carbon nanofibers are separated from the surfaces of fine particles by a physical process or a chemical process and the carbon nanofibers are recovered.

2. The producing method of carbon nanofibers according to claim 1,
10 wherein the growth reaction for carbon nanofibers is performed by either one of a gas flow layer reaction process, a fixed layer reaction process and a moving layer reaction process and a fluidizing layer reaction process.

- 15 3. The producing method of carbon nanofibers according to claim 2, wherein, when the growth reaction for carbon nanofibers is the fluidizing layer reaction process, carbon nanofibers are caused to grow on the surfaces of fine particles utilizing fine particles as fluidizing material, simultaneously with growth of the carbon nanofibers, carbon
20 nanofibers are separated by collision among fine particles, and carbon nanofibers are recovered.

- 25 4. The producing method of carbon nanofibers according to claim 2, wherein, when the growth reaction for carbon nanofibers is the fluidizing layer reaction process, for causing carbon nanofibers to grow

on the surfaces of fine particles utilizing fine particles as fluidizing material, a calm fluidizing state is set and the fine particles are violently stirred after reaction termination to separate carbon nanofibers by collision among the fine particles, and carbon nanofibers are recovered.

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5. The producing method of carbon nanofibers according to claim 1, wherein the fine particles are closely packed fine particles.

10 6. The producing method of carbon nanofibers according to claim 5, wherein the closely packed fine particles are non-porous high strength closely packed fine particles.

15 7. The producing method of carbon nanofibers according to claim 6, wherein a void ratio of the closely packed fine particles is 10% or less.

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8. The producing method of carbon nanofibers according to claim 1, wherein the fine particles include one kind of or a mixture of two or more kinds of silica sand, aluminosilicate, zeolite aluminum oxide, zirconium oxide, silicon carbide, silicon nitride, limestone, dolomite and 20 the like, or one kind of the compounds thereof as a main component and the main component is included in an amount of 50 weight % or more.

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9. The producing method of carbon nanofibers according to claim 1, 25 wherein fine particles from which the carbon nanofibers have been

separated are recycled for reaction.

10. The producing method of carbon nanofibers according to claim 1, wherein catalyst component is adhered to the fine particles.

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11. The producing method of carbon nanofibers according to claim 10, wherein the catalyst component is metal of one kind of or a combination of two or more kinds of Na, K, Mg, Ca, Sr, Ba, Cr, Mn, Fe, Co, Ni, Mo, W, Ru, Rh, Pd, Ir, Pt or lanthanoid element such as La, Ce 10 or Pr, oxide, chloride or nitrate thereof.

12. The producing method of carbon nanofibers according to claim 11, wherein the catalyst contains S component.

15 13. The producing method of carbon nanofibers according to claim 10, wherein additive particles for peeling off carbon nanofibers, which is different from the catalyst in particle shape, size and material quality is used to separate carbon nanofibers.

20 14. The producing method of carbon nanofibers according to claim 1, wherein growth of the carbon nanofibers are conducted plural times.

15. The producing method of carbon nanofibers according to claim 1, wherein carbon nanofibers peeled off from the fine particles are washed 25 with acidic solution, additives having a functional group with high affinity

with carbon nanofibers or having a functional group with lipophilic property and organic compound which is liquid in the normal temperature are mixed and added in acidic solution including the produced carbon nanofibers dissolved to disperse the carbon

5 nanofibers in the organic compound solution, and the organic compound solution with the carbon nanofibers dispersed is evaporated to obtain carbon nanofibers.

16. The producing method of carbon nanofibers according to claim
10 15, wherein the additive is a compound having a polynuclear aromatic functional group.

17. The producing method of carbon nanofibers according to claim
16, wherein the compound having a polynuclear aromatic functional
15 group is either one of anthracene, pyrene and chrysene, or a mixture thereof.

18. The producing method of carbon nanofibers according to claim
15, wherein the organic compound that is liquefied in the normal
20 temperature includes either one of normal hexane, toluene, tetrahydrofuran, dimethylformamide, chloromethane, and the like, or a combination of at least two thereof.

19. A producing apparatus of carbon nanofibers comprising:
25 a reaction apparatus that supplies carbon raw material and fine

particles to cause carbon nanofibers to grow on surfaces of the fine particles;

a heating apparatus that heats the reaction apparatus;

a recovery line that recovers fine particles on which the carbon

5 nanofibers have grown from the reaction apparatus; and

a carbon nanofiber separating apparatus that separates carbon nanofibers from the recovered fine particles on which carbon nanofibers have been grown.

10 20. The producing apparatus of carbon nanofibers according to claim 19, wherein the reaction apparatus is one of a gas flow layer reaction apparatus, a fixed layer reaction apparatus, a moving layer reaction apparatus and a fluidizing layer reaction apparatus.

15 21. The producing apparatus of carbon nanofibers according to claim 19, wherein a catalyst supplying apparatus that supplies catalyst to the reaction apparatus is provided.

22. The producing apparatus of carbon nanofibers according to
20 claim 21, wherein the catalyst supplying apparatus is a liquefied state supplying apparatus that supplies catalyst dissolved in carbon raw material into the reaction apparatus in a liquefied state.

23. The producing apparatus of carbon nanofibers according to
25 claim 21, wherein the catalyst supplying apparatus that supplies

catalyst into the reaction apparatus in a solid state or a gaseous state.

24. The producing apparatus of carbon nanofibers according to
claim 21, wherein the catalyst supplying apparatus that supplies fine
5 particles carrying catalyst on surfaces thereof into the reaction
apparatus.

25. The producing apparatus of carbon nanofibers according to
claim 24, wherein the catalyst carrying apparatus carrying catalyst on
10 surfaces of fine particles is provided with a fine particle supplying
apparatus that supplies fine particles into a carrying vessel main body,
and a spraying unit that sprays catalyst to fine particles supplied to the
carrying vessel main body.

15 26. The producing apparatus of carbon nanofibers according to
claim 25, wherein the carrying vessel main body is of a fluidizing layer
type and has a gas supplying apparatus that supplies fluidizing gas.

27. The producing apparatus of carbon nanofibers according to
20 claim 25, wherein the carrying vessel main body is of kiln type and has
a rotary drum.

28. The producing apparatus of carbon nanofibers according to
claim 19, wherein an average particle diameter of the fine particles is in
25 a range of 0.2 to 20nm.

29. The producing apparatus of carbon nanofibers according to
claim 19, wherein the fine particles are closely packed fine particles.

5 30. The producing apparatus of carbon nanofibers according to
claim 29, wherein the closely packed fine particles are non-porous high
strength closely packed fine particles.

10 31. The producing apparatus of carbon nanofibers according to
claim 29, wherein a void ratio of the closely packed fine particles is 10%
or less.

15 32. The producing apparatus of carbon nanofibers according to
claim 19, wherein the fine particles include one kind of or a mixture of
two or more kinds of silica sand, aluminosilicate, zeolite aluminum oxide,
zirconium oxide, silicon carbide, silicon nitride, limestone, dolomite and
the like, or one kind of the compounds thereof as a main component
and the main component is included in an amount of 50 weight % or
more.

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33. The producing apparatus of carbon nanofibers according to
claim 19, wherein a reaction temperature at a time of contact between
the catalyst and the carbon raw material is in a range of 300°C to
1300°C, and a pressure is 0.01MPa or more.

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34. The producing apparatus of carbon nanofibers according to claim 19, wherein a collision unit that collides against fine particles is provided in the reaction apparatus.

5 35. The producing apparatus of carbon nanofibers according to claim 34, wherein the collision unit also serves as a heat transfer tube for temperature adjustment inside the reaction layer.